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Energy Efficiency and Material Cost Savings by Evolution of Solar Panels Used in Photovoltaic Systems under Neutrosophic Model

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Abstract: Traditional applications of solar panels have been limited to smaller-scale energy production, such as that required by single houses or apartment complexes. Researchers from all around the globe have been working together to develop creative, efficient goods, increase the energy efficiency of solar panels, and build new, ground-breaking practices using photovoltaic system design. Solar photovoltaic (PV) system planning demands a strategic decision-making approach to socioeconomic growth in many nations due to the rising understanding of the financial, social, and ecological aspects. The primary goal of this study is to provide a novel, adaptable method of Multi-Criteria Decision Making (MCDM) for government decision-makers (DMs) to use in evaluating solar PV panel manufacturers using various variables. This paper used the single-valued neutrosophic set to deal with the vague data. The neutrosophic set is used with the Characteristic Objects Method (COMET). The COMET method is an MCDM method. It is used to compute the rank of alternatives. The application of the proposed method is introduced with eleven criteria and ten solar panels in PV.

Keywords: Solar Panels; Photovoltaic System; Energy Efficiency; Neutrosophic Set.

1. Introduction

Photovoltaic (PV) systems, which utilize sunlight to generate electricity, are one of the most popular forms of renewable energy generating. Solar PV energy has the greatest electricity density and requires the least amount of preservation contrasting to other renewable energy sources. It also produces no harmful emissions during operation and helps mitigate global warming. Despite the PV technological many benefits, the transformation system is vulnerable to a number of environmental factors that might reduce its performance, including hail, dust, and high surface operating temperatures [1, 2].

The outermost temperature of a photovoltaic panel is often affected by exogenous meteorological conditions, including wind speed, atmospheric humidity, temperatures, collected dust, and sunlight. The effectiveness of a solar panel decreases by 0.5% for every 1°C increase in its outermost temperature. Therefore, as a result of the increase in temperature, the efficiency with which solar energy is transformed into electrical power decreases. The leftover solar energy is turned into heat, which satisfies the law of preservation of energy. The total conversion efficiency suffers as a result of this lost heat [3]–[5].

For solar systems to convert energy to be a practical option, they need to increase their efficiency. In order for this to be a workable option, we need to figure out how to reduce the impact of the temperature rise on the conversion effectiveness.

With the goal of boosting the overall effectiveness of the solar converting system, only a few writers have attempted to compile and perform an exhaustive study of alternative technologies that may be used to cool the operational surface of solar panels [6, 7].

Options, standards, and the expert's assessment of the importance of the criteria and the extent to which the requirements are satisfied by other options all make up the decision-making procedure. Ambiguity and unpredictability play a role in the process of prioritizing options by taking criteria into account. Fuzzy decision-making technologies are used to address such cases [8]–[10].

Zadeh is widely regarded as the father of fuzzy set theory, which has since been expanded to include interval-valued fuzzy sets by Turksen, intuitionistic fuzzy sets by Atanssov, hesitant sets by Tora, and Neutrosophic fuzzy sets by Florentin Smarandache. Many different approaches to making decisions have been developed by scholars, from group consensus to the use of many factors [11, 12].

2. Suitability Energy

Critical concerns influencing global sustainability include warming temperatures and the development of environmentally friendly energy systems. Important topics, such as climate change and air pollution, were discussed at the United Nations Climate Change Conference (COP25) in 2019. The dangers of airborne contaminants to human health were discussed, in addition to the present severity of anomalous climates and warm temperatures throughout the globe. Machines have gradually replaced humans in the workplace and made it possible to extract and use natural resources (such as coal, oil, natural gas, and different minerals) at an unprecedented scale since the nineteenth-century industrial period [13, 14].

While the rise of industry and its repercussions were vital to economic growth in many nations, they also left behind a legacy of contamination of the environment and other difficulties as a result of massive amounts of CO2. This has triggered irreversible, aberrant climatic conditions (such as severe cold, extreme heat, floods, and drought) and exacerbated worldwide warming and environmental degradation. Climate calamities will only become worse if action isn't taken. Many island states may not survive if conditions persist at their current levels.

According to IPCC's (a United Nations organization) 2019 annual report, global temperatures are now around 1°C higher than they were during the industrialization era. As global temperatures rise, so do the natural disasters that result from them. Natural catastrophes will have a bigger effect on human life and property when the temperature rise reaches 1.5°C; when it reaches 1.5-2 °C, the world will be swept with both predictable (such as stored-grain infestations, rising temperatures, droughts, and changes of forest environmental systems) and unpredictable catastrophes due to climate change.

High CO2 emissions are a critical ecological management problem that the world must face as a cost of economic success and fast technological progress. It's unclear whether we'll be able to stop the world from becoming warmer. Temperatures exceeding 20 degrees Celsius were recorded in Antarctica in February of the year 2020, signaling an acceleration in the rate at which ice is melting and sea levels are increasing [15, 16].

3. Solar Panels

Traditional applications of solar panels have been limited to smaller-scale energy production, such as that required by single houses or apartment complexes. There are two crystal kinds, polycrystalline and monocrystalline, that provide these panels with a wide efficiency range. Polycrystalline displays are often less efficient than monocrystalline panels owing to the existence of just one crystal, but they are less costly. The overall price of a solar panel is based on its power output (in watts), manufacturer, dimensions, expected lifespan, and approvals.

Choosing a panel only based on its price is not a good idea since it may not work in the intended location, might not be certified to qualify for government rebates, and might not have a long enough warranty to cover the cost of installation and maintenance in a timely manner. Solar panels have a longer payback period than other power generation methods due to the high cost per kilowatt-hour of electricity generated. Consumers are unlikely to adopt solar system technologies with a lengthy payback time. The sooner an investor may recoup their initial investment via the sale of excess power to the grid or the use of a 'free' source of electricity, the better the efficiency of their solar panels. Therefore, choosing these solar panels is a crucial step in developing a photovoltaic system [17, 18].

4. Renewable Energy

Energy is crucial to the continued development of countries. Fossil fuels have been the world's primary energy source for decades. However, global energy use has been placed under considerable pressure as a result of rapid population growth, increasing levels of living, and the proliferation of power-consuming enterprises in both established and developing countries. The fast increase in emissions of environmental pollutants such as carbon dioxide and methane as a consequence of this trend has highlighted two major concerns: the decline of the most readily accessible energy sources (primarily oil) and the issue of climate change. The globe is confronting the issue of combating climate change and warming temperatures via the use of safe and cost-effective renewable energy (RE) sources. The International Renewable Energy Agency (IRENA) predicts a 50% growth in RE-based potential worldwide between 2019 and 2024, amounting to an additional 1220 Gigawatts [19, 20].

Energy harvested from the sun, rainfall, wind, tides, and geothermal radiation are all examples of renewable energy. When compared to conventional sources of energy (e.g. coal, oil, and petroleum), the environmental effect of green energy is negligible, and there are no byproducts of carbon dioxide. Therefore, green energies seem to be the most viable option for addressing ecological issues and worries about energy security. The sun provides a source of a great deal of renewable energy. Solar energy has emerged as the most promising RE source because of its widespread availability, adaptability, and very simple deployment with negligible land-use impacts. Harvesting the sun's rays and using them as a source of power is what is meant by the phrase "solar energy." A large portion of the global demand for energy may be met by harnessing the sun's daily output of power (such as in one hour, the planet gets 172 000 TWh of power from the sun) [21, 22].

Solar PV systems and concentrating solar-thermal power (CSP) systems, which use heat from the sun to turn traditional turbines, are two methods for harnessing the sun's energy for electrical production.

5. Photovoltaic Systems

These days, PV systems are among the most widely used means of producing electrical power. The global PV energy industry is growing rapidly, but many countries, especially those with densely populated cities, are running out of room. That is to say, it is getting more difficult to find enough space for the installation of additional PV panels, which are normally roof- or ground-mounted. PV systems are inefficient; hence a large plot of land is required (about 10 square meters per kilowatt peak). To deal with these issues and free up space for farming, housing, and other uses, solar energy plants may be installed on water bodies including lakes, dam reservoirs, waterways, and rivers. Furthermore, the effectiveness of solar panels is increased by the cooling effect of water on floating solar power plants (FPVSs) [23, 24]. A PV system is comprised of a PV panel or array, the main part that transforms solar energy into direct current (DC) power, as well as auxiliary parts that serve for storing and disseminating the energy. It can be seen in Figure 1 that there are four main parts to a typical solar power plant. These parts are the PV module (or PV array), the battery, the charge controller, and the inverter. As the PV modules generate more energy than is immediately needed, the excess is stored in batteries for use at night or on periods with low sunshine or overcast weather. The life of the batteries is prolonged by the charge controller, which prevents them from being overloaded or completely depleted. Then the neutrosophic Characteristic Objects Method (COMET) is applied to select the best solar panels.

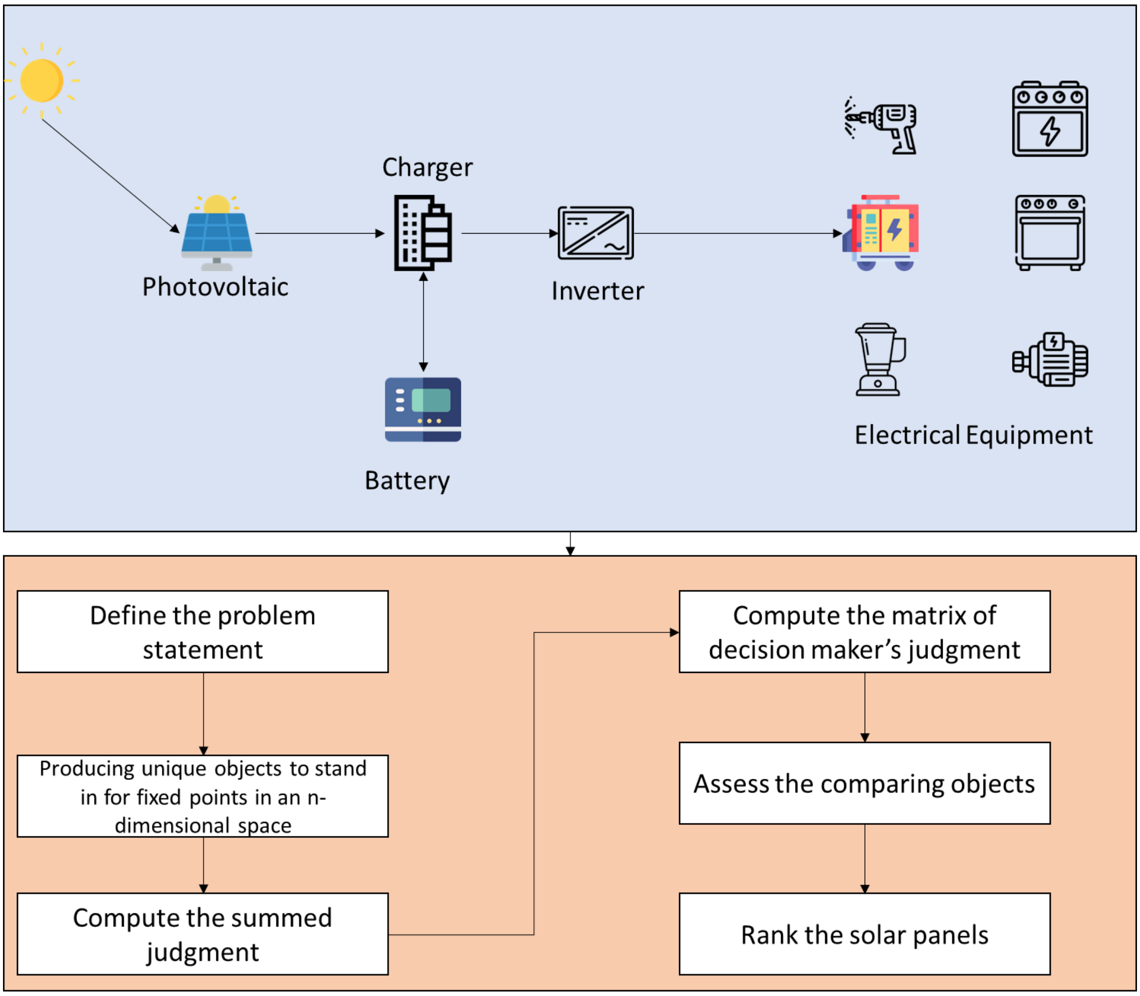

Figure 1. Photovoltaic system and solar panels selection.

6. Neutrosophic COMET Method

The COMET is a novel method for resolving decision-making issues by the identification of several criteria using an expert decision-making model [25, 26]. The novel approach presented here has the major benefit of being completely resistant to the order of solar panels. The steps of this process are outlined below.

i. Define the problem statement

The problem is defined by gathering the set of criteria and set of alternatives based on solar panels. These criteria and alternatives are gathering from previous studies, and evaluated by the single valued neutrosophic numbers.

ii. Producing unique objects to stand in for fixed points in an n-dimensional space.

These things could really exist in the world, or they might just be hypothetical.

$$O_1 = \left(SPC(SPC_{11}), SPC(SPC_{21}), \dots \dots .. SPC(SPC_{r1})\right) \quad (1)$$

$$O_2 = \left(SPC(SPC_{11}), SPC(SPC_{21}), \dots \dots .. SPC(SPC_{r2})\right) \quad (2)$$

$$O_3 = \left(SPC(SPC_{11}), SPC(SPC_{21}), \dots \dots .. SPC(SPC_{r3})\right) \quad (3)$$

$$O_4 = \left(SPC(SPC_{11}), SPC(SPC_{21}), \dots \dots .. SPC(SPC_{r4})\right) \quad (4)$$

$$O_t = \left(SPC(SPC_{1SPC1}), SPC(SPC_{2SPC1}), \dots \dots .. SPC(SPC_{rSPC1})\right) \quad (5)$$

Where SPC refers to the criteria of solar panels.

iii. Compute the matrix of decision maker's judgment.

The criteria and alternatives are evaluated by the decision makers with the single valued neutrosophic numbers.

$$MX = \begin{bmatrix} x_{11} & \cdots & x_{1t} \\ \vdots & \ddots & \vdots \\ x_{t1} & \cdots & x_{tt} \end{bmatrix} \quad (6)$$

Where x_{11} refers to the comparing (SPC_i) and (SPC_j)

iv. Assess the comparing objects.

$$x_{ij} = \begin{cases} 0, & s_{exp}(SPC_i) < s_{exp}(SPC_j) \\ 0.5, & s_{exp}(SPC_i) = s_{exp}(SPC_j) \\ 1.0, & s_{exp}(SPC_i) > s_{exp}(SPC_j) \end{cases} \quad (7)$$

Where s_{exp} refers to the function of decision makers with the judgment.

v. Compute the summed judgment (JU)

The JU is computing by the vertical vector as:

$$JU = \sum_{j=1}^{t} x_{ij} \quad (8)$$

7. Solar Panels Results

This section ranks the solar panels based on various criteria. These paper used ten alternatives and eleven criteria like Open Circuit Voltage, Short Circuit Current, Module Efficiency, Peak Power, Cost, Weight, Area, Material, Service support, Spare part, and Reliability.

Using alternative energy sources extensively to satisfy increasing energy needs not only saves money as opposed to alternatives such as fossil fuels but also lessens the country's reliance on imported goods, which in turn helps the economy thrive. Particularly in poor nations, where the cost of installing and maintaining solar PV systems is cheap, utilizing them to produce power raises GDP and the quality of life. Levelized cost of electricity (LCOE), capacity factor, and overall installed price of a solar photovoltaic structure, weighted globally.

This section offers the result of the single valued neutrosophic COMET method. The experts are evaluated the criteria and alternatives. Then we replace their opinions by the single valued neutrosophic numbers. Then assessing the objects by the comparison as shown in Tables 1-3. Then compute the scores of summed judgments as shown in Figure 2. The option 10 is the best and alternative 8 is the worsts.

Table 1. The Assessment of the comparing first and second object.

	SPC_1	SPC_2	SPC_3	SPC_4	SPC_5	SPC_6	SPC_7	SPC_8	SPC_9	SPC_9	SPC_{10}
SPA_1	1	0	0	1	0	0	1	1	0	0.5	1
SPA_2	1	0	0	1	0	0	0	1	0	0	1
SPA_3	1	0	0	1	0	0	0	1	1	0	1
SPA_4	1	0	0	1	0	0	0.5	1	0	0.5	1
SPA_5	1	0	0	1	1	0	1	1	0	0.5	1
SPA_6	0.5	0	0	1	0	0	0.5	1	0.5	0	1
SPA_7	1	0	0	1	0.5	0	0.5	1	0	0.5	1
SPA_8	1	0	0	1	0	0	0.5	1	0	0.5	1
SPA_9	0.5	0.5	0.5	0.5	0.5	0	0	0.5	0	1	0.5
SPA_{10}	1	1	1	1	1	1	1	1	1	1	1

Table 2. The Assessment of the comparing second and third object.

	SPC_1	SPC_2	SPC_3	SPC_4	SPC_5	SPC_6	SPC_7	SPC_8	SPC_9	SPC_9	SPC_{10}
SPA_1	0.5	1	1	0.5	1	1	0.5	0.5	1	0.5	0.5
SPA_2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SPA_3	1	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SPA_4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5
SPA_5	0.5	0.5	0.5	1	0.5	0.5	0.5	1	0.5	0.5	0.5
SPA_6	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5
SPA_7	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	1	0.5	0.5
SPA_8	0.5	0.5	0.5	1	1	0.5	0.5	0.5	0.5	0.5	0.5
SPA_9	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SPA_{10}	0.5	1	1	0.5	1	0.5	0.5	0.5	0.5	1	0.5

Table 3. The Assessment of the comparing third and fourth object.

	SPC_1	SPC_2	SPC_3	SPC_4	SPC_5	SPC_6	SPC_7	SPC_8	SPC_9	SPC_9	SPC_{10}
SPA_1	0.5	1	1	0.5	1	1	1	0.5	1	1	0.5
SPA_2	0.5	1	0.5	0.5	1	0.5	1	0.5	1	1	1
SPA_3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SPA_4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	1
SPA_5	0.5	1	0.5	0.5	0.5	0.5	1	1	0.5	1	0.5
SPA_6	0.5	0.5	0.5	0.5	1	0.5	1	0.5	1	1	0.5
SPA_7	0.5	1	0.5	0.5	0.5	0.5	1	0.5	1	0.5	1
SPA_8	0.5	1	0.5	0.5	1	0.5	1	0.5	0.5	1	0.5
SPA_9	0.5	1	0.5	0.5	1	0.5	1	0.5	1	1	0.5
SPA_{10}	0.5	1	1	0.5	1	0.5	0.5	0.5	1	1	0.5

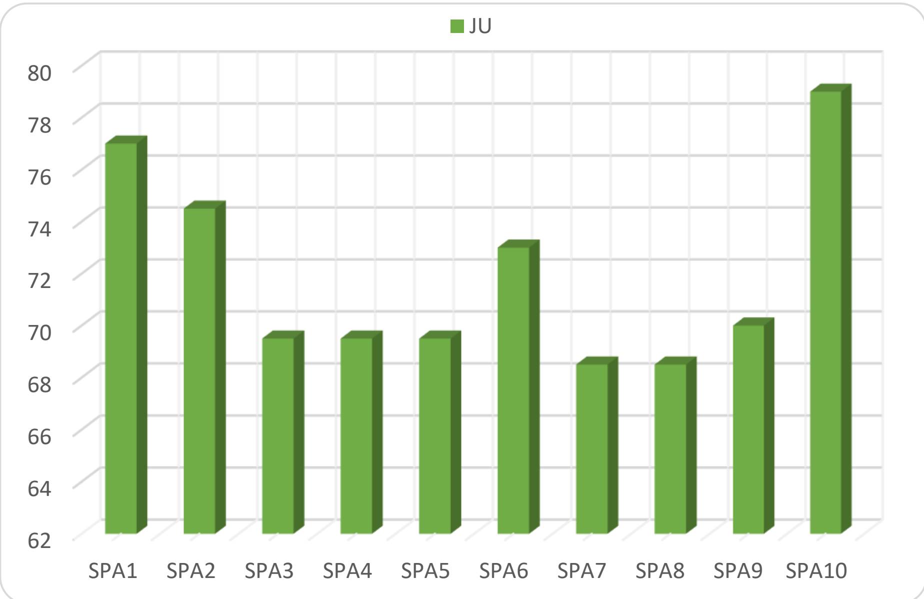

Figure 2. The scores of summed judgments (JU).

8. Conclusion

Developments in international energy sources raise greenhouse gas emissions and fossil fuel costs in response to rising energy demand. Solar energy is a clean, renewable energy source that may cover energy needs at lower costs and presents economic opportunities, especially in rural regions.

Because of the enormous opportunity for solar energy, policymakers have been focusing more on solar energy expenditures in recent years. This paper proposed a single-valued neutrosophic set with the COMET method to deal with uncertain data and rank the alternatives. This paper used 11 factors and 10 alternatives.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. C.-N. Wang, V. T. Nguyen, H. T. N. Thai, and D. H. Duong, "Multi-criteria decision making (MCDM) approaches for solar power plant location selection in Viet Nam," Energies, vol. 11, no. 6, p. 1504, 2018.
2. R. Ghasempour, M. A. Nazari, M. Ebrahimi, M. H. Ahmadi, and H. Hadiyanto, "Multi-Criteria Decision Making (MCDM) Approach for Selecting Solar Plants Site and Technology: A Review.," Int. J. Renew. Energy Dev., vol. 8, no. 1, 2019.
3. C.-R. Chen, C.-C. Huang, and H.-J. Tsuei, "A hybrid MCDM model for improving GIS-based solar farms site selection," Int. J. Photoenergy, vol. 2014, 2014.
4. M. Majumder and A. K. Saha, Feasibility model of solar energy plants by ANN and MCDM techniques. Springer, 2016.
5. S.-L. Hsueh, Y. Feng, Y. Sun, R. Jia, and M.-R. Yan, "Using AI-MCDM model to boost sustainable energy system development: A case study on solar energy and rainwater collection in guangdong province," Sustainability, vol. 13, no. 22, p. 12505, 2021.
6. S. Seker and C. Kahraman, "Socio-economic evaluation model for sustainable solar PV panels using a novel integrated MCDM methodology: A case in Turkey," Socioecon. Plann. Sci., vol. 77, p. 100998, 2021.
7. C.-N. Wang, T.-T. Dang, and J.-W. Wang, "A combined Data Envelopment Analysis (DEA) and Grey Based Multiple Criteria Decision Making (G-MCDM) for solar PV power plants site selection: A case study in Vietnam," Energy Reports, vol. 8, pp. 1124–1142, 2022.
8. S. Broumi et al., "Interval valued pentapartitioned neutrosophic graphs with an application to MCDM," Oper. Res. Eng. Sci. Theory Appl., vol. 5, no. 3, pp. 68–91, 2022.
9. J. S. M. Donbosco and D. Ganesan, "The Energy of rough neutrosophic matrix and its application to MCDM problem for selecting the best building construction site," Decis. Mak. Appl. Manag. Eng., vol. 5, no. 2, pp. 30–45, 2022.
10. M. R. Ahmad, M. Saeed, U. Afzal, and M.-S. Yang, "A novel MCDM method based on plithogenic hypersoft sets under fuzzy neutrosophic environment," Symmetry (Basel)., vol. 12, no. 11, p. 1855, 2020.
11. J. Więckowski and J. Wątróbski, "How to determine complex MCDM model in the COMET method? Automotive sport measurement case study," Procedia Comput. Sci., vol. 192, pp. 376–386, 2021.
12. X. Wu and X. Zhang, "The decomposition theorems of AG-neutrosophic extended triplet loops and strong AG-(l, l)-loops," Mathematics, vol. 7, no. 3, p. 268, 2019.
13. A. Almasad, G. Pavlak, T. Alquthami, and S. Kumara, "Site suitability analysis for implementing solar PV power plants using GIS and fuzzy MCDM based approach," Sol. Energy, vol. 249, pp. 642–650, 2023.
14. J. M. Sánchez-Lozano, J. Teruel-Solano, P. L. Soto-Elvira, and M. S. García-Cascales, "Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) methods for the evaluation of solar farms locations: Case study in south-eastern Spain," Renew. Sustain. energy Rev., vol. 24, pp. 544–556, 2013.

15. A. Bączkiewicz, B. Kizielewicz, A. Shekhovtsov, M. Yelmikheiev, V. Kozlov, and W. Sałabun, "Comparative analysis of solar panels with determination of local significance levels of criteria using the mcdm methods resistant to the rank reversal phenomenon," Energies, vol. 14, no. 18, p. 5727, 2021.
16. H. Aljaghoub, F. Abumadi, M. N. AlMallahi, K. Obaideen, and A. H. Alami, "Solar PV cleaning techniques contribute to Sustainable Development Goals (SDGs) using Multi-criteria decision-making (MCDM): Assessment and review," Int. J. Thermofluids, vol. 16, p. 100233, 2022.
17. M. Mokarram, T. M. Pham, and M. H. Khooban, "A hybrid GIS-MCDM approach for multi-level risk assessment and corresponding effective criteria in optimal solar power plant," Environ. Sci. Pollut. Res., vol. 29, no. 56, pp. 84661–84674, 2022.
18. H. A. Xuan, V. V. Trinh, K. Techato, and K. Phoungthong, "Use of hybrid MCDM methods for site location of solar-powered hydrogen production plants in Uzbekistan," Sustain. Energy Technol. Assessments, vol. 52, p. 101979, 2022.
19. R. Malemnganbi and B. A. Shimray, "Solar power plant site selection: a systematic literature review on MCDM techniques used," Electron. Syst. Intell. Comput. Proc. ESIC 2020, pp. 37–48, 2020.
20. G. Villacreses, J. Martinez-Gomez, D. Jijon, and M. Cordovez, "Geolocation of photovoltaic farms using Geographic Information Systems (GIS) with Multiple-criteria decision-making (MCDM) methods: Case of the Ecuadorian energy regulation," Energy Reports, vol. 8, pp. 3526–3548, 2022.
21. M. Jahangiri, A. A. Shamsabadi, A. Mostafaeipour, M. Rezaei, Y. Yousefi, and L. M. Pomares, "Using fuzzy MCDM technique to find the best location in Qatar for exploiting wind and solar energy to generate hydrogen and electricity," Int. J. Hydrogen Energy, vol. 45, no. 27, pp. 13862–13875, 2020.
22. T.-C. Wang and S.-Y. Tsai, "Solar panel supplier selection for the photovoltaic system design by using fuzzy multi-criteria decision making (MCDM) approaches," Energies, vol. 11, no. 8, p. 1989, 2018.
23. S. Narayanamoorthy et al., "The novel augmented Fermatean MCDM perspectives for identifying the optimal renewable energy power plant location," Sustain. Energy Technol. Assessments, vol. 53, p. 102488, 2022.
24. G. Van de Kaa, J. Rezaei, L. Kamp, and A. de Winter, "Photovoltaic technology selection: A fuzzy MCDM approach," Renew. Sustain. Energy Rev., vol. 32, pp. 662–670, 2014.
25. W. Sałabun, A. Karczmarczyk, J. Wątróbski, and J. Jankowski, "Handling data uncertainty in decision making with COMET," in 2018 IEEE Symposium Series on Computational Intelligence (SSCI), IEEE, 2018, pp. 1478–1484.
26. W. Sałabun and A. Piegat, "Comparative analysis of MCDM methods for the assessment of mortality in patients with acute coronary syndrome," Artif. Intell. Rev., vol. 48, pp. 557–571, 2017.

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